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Christian Keuschnigg and Evelyn Ribi

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Department of Economics University of St. Gallen

Editor:	Martina Flockerzi University of St. Gallen Department of Economics Varnbüelstrasse 19 CH-9000 St. Gallen Phone +41 71 224 23 25 Fax +41 71 224 31 35 Email vwaabtass@unisg.ch
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Christian Keuschnigg und Evelyn Ribi

Author's address: Prof. Christian Keuschnigg
IFF-HSG
Varnbüelstrasse 19
9000 St. Gallen
Tel. +41 71 224 25 20
Fax +41 71 224 26 70
Email christian.keuschnigg@unisg.ch
Website www.iff.unisg.ch

Dr. Evelyn Ribi
IFF-HSG
Varnbüelstrasse 19
9000 St. Gallen
Tel. +41 71 224 3087
Fax +41 71 224 2670
Email evelyn.ribi@unisg.ch

Abstract

Credit constraints are more frequent among growth companies with large investment opportunities. For the same reason, profit taxes may harm innovative firms more than standard ones. This paper develops a model of heterogeneous firms where an endogenous share opts for innovation and faces credit constraints in the subsequent expansion phase. We emphasize four results: (i) R&D subsidies not only encourage innovation but also relax finance constraints and help innovative firms to exploit investment opportunities to a larger extent. (ii) Taxes which are neutral in a neoclassical world, still restrict expansion investment of constrained firms by reducing free cash-flow and thereby discourage innovation. (iii) A revenue neutral increase in profit taxes to finance larger R&D subsidies redistributes towards innovative firms and boosts aggregate productivity and welfare. (iv) A revenue neutral tax cut cum base broadening policy similarly boosts innovation and welfare.

JEL-Classification

G32, G38, H25.

Keywords

Profit taxes, R&D subsidies, innovation, investment, credit constraints.

1 Introduction

Growth opportunities are distributed unevenly in the business sector. Empirical evidence suggests a heterogeneity of firms along several dimensions and points to three important characteristics. First, small entrepreneurial companies are often very dynamic and more innovative than more mature firms. The innovative nature of their business model creates large investment opportunities. Second, the growth prospects of these firms depend on the technological know-how and managerial effort of a dominating entrepreneur. And third, young growth companies tend to have little own assets either because they are at an early stage of their life-cycle or because own resources have been drained at an early stage by substantial spending on R&D (research and development). The combination of these characteristics, i.e. large investment opportunities, little own resources and potential moral hazard with respect to entrepreneurial effort, makes it likely that these firms face credit constraints. Compared to innovative firms, other less dynamic companies pursue more standard and mature concepts and, as a consequence, have less potential to invest and grow. These firms are less likely to face restrictions in external financing.

A large empirical literature emphasizes the prevalence and importance of credit constraints. Rajan and Zingales (1998) document important sectoral differences in the external financial dependence of firms. Accordingly, financial sector development stimulates mostly the expansion of financially dependent sectors relative to other sectors. In general, young and small firms are more likely to be credit constrained than large firms (cf. Schaller, 1993; Jaramillo, Schiantarelli, and Weiss, 1996; Beck, Demirguc-Kunt, and Maksimovic, 2005; Aghion, Fally, and Scarpetta, 2007). Both firm entry and subsequent firm growth are limited by financial frictions (see Hubbard, 1998; Beck and Demirguc-Kunt, 2006; Aghion et al., 2007). Furthermore, empirical research commonly finds that innovative firms face tighter financing restrictions than non-innovative firms (Guiso, 1998; Hyytinen and Toivanen, 2005; Ughetto, 2009; Hall and Lerner, 2009). With these classes of firms most strongly affected, financial constraints are not only important at the firm level but are likely to slow down macroeconomic performance as well. Young and innovative firms have emerged as an important source of economic growth (Audretsch, 2002; Carree and Thurik, 2003). These firms are fast in adopting and developing new technologies or products, and consequently grow at a faster pace than larger established firms. Despite their small initial size, they contribute significantly to aggregate employment and productivity growth (cf. Roper, 1997; Audretsch, 2002). Kortum and Lerner (2000) attribute in 1998 roughly 14% of U.S. industrial innovation to young venture capital backed firms although they spend only about 3% of total R&D funds.

This paper explores how tax policy may influence innovation and aggregate investment when firms are heterogeneous and expansion investment of innovative companies is constrained by the availability of external funding. This endeavor is likely to be important since empirical research suggests that constrained and unconstrained firms respond in an entirely different way to profit taxation. According to neoclassical theory, taxes affect investment of unconstrained firms exclusively by their impact on the user cost of capital (e.g. Hall and Jorgensen, 1967; Auerbach, 1983). Hassett and Hubbard (2002) review the empirical literature and report estimates of investment elasticities with respect to user cost in the range between -0.5 and -1.0. In contrast, investment becomes sensitive to cash-flow and own collateral when firms are finance constrained (see Hubbard, 1998, for a survey). Schaller (1993), Chirinko and Schaller (1995) and Hoshi, Kashyap and Scharfstein (1991) report elasticities of physical capital investment to cash-flow around 0.4-0.5. Estimates for total working capital are significantly higher and vary between 0.8 to 1.3 (see Fazzari and Petersen, 1993; Calomiris and Hubbard, 1995; and Carpenter and Petersen, 2002). The user cost of capital – and thereby the marginal effective tax rate – is not important for constrained firms since they are unable to invest up to the efficient scale which would equate the return on investment to the user cost. In fact, because these firms are constrained, they earn an excess return on top of the user cost. For these reasons, neutral tax systems such as cash-flow taxes or an ACE system (allowance for corporate equity) cannot be neutral if at least part of firms are finance constrained (see Keuschnigg and Ribi, 2009).[1] Although these tax systems have no impact on the user

[1] The ACE system was proposed by the Capital Taxes Group of the Institute for Fiscal Studies (1991)

cost, they still retard investment of constrained firms by reducing free cash-flow. Given that finance constrained firms are often the most innovative ones, it seems important to explore how tax policy can endogenously affect not only investment scale but also the share of constrained firms and, thereby, aggregate innovation.

To investigate these issues, we propose a theoretical model where innovative firms face credit constraints. In a first stage, firms decide whether to make a discrete R&D investment or not. This decision margin endogenously explains the composition of the business sector between innovative and standard firms and, depending on the shares of these firms, aggregate productivity. The R&D investment has two consequences: it boosts productivity and, thereby, creates larger investment opportunities of innovating firms in the subsequent expansion stage. It also drains internal resources relative to standard firms which abstain from R&D and remain with lower productivity. Both consequences make it likely that innovative growth companies face credit constraints in the subsequent expansion phase. Subsequent to the innovation decision, firms are heterogeneous with respect to investment opportunities. Standard firms have low productivity and, in turn, only moderate growth prospects and their internal resources are undiminished by R&D expenses. These firms need little external funding and are not credit constrained. They invest until the rate of return is equal to the user cost of capital, i.e. neoclassical investment theory applies. Innovative firms, in contrast, have a large need for external funding and are, by assumption, credit constrained. Their investment is determined by own resources which are leveraged with external funds up to a maximum limit which depends on pledgeable future cash-flow. Following Holmstrom and Tirole (1997) and Tirole (2006), a firm's pledgeable income reflects a moral hazard problem with respect to entrepreneurial

and allows firms to deduct an imputed return on equity in addition to interest on debt. A cash-flow tax (recommended by Meade, 1978) allows deduction of investment costs upfront but denies any deduction of financing costs ex post. These tax systems were shown to be neutral in the absence of financial frictions (see King, 1975; Sandmo, 1979; Boadway and Bruce, 1984, for models under certainty, and Bond and Devereux, 1995, 2003, under uncertainty) and feature prominently in the tax reform literature (e.g. Devereux and Sorensen, 2005; OECD, 2007; Auerbach, Devereux, and Simpson, 2008). We can replicate these neutrality results as long as finance constraints are not binding.

effort. Entrepreneurs need to keep a minimum part of the company's earnings to assure their high effort which limits the amount of income that can credibly be promised to banks and other external investors as a repayment. As a result, banks restrict credit, implying that a firm's investment at the margin is limited by its capacity to leverage own assets with external credit. Since investment is lower than the unrestricted level, innovative but finance constrained firms generate an excess return on investment.

Our model of constrained and unconstrained firms or, equivalently, of innovative and standard firms, allows us to study the effects of tax policy on innovation, capital investment and welfare. The analysis highlights transmission channels for tax policy that are entirely different across firms, depending on their financing capacity. We derive four novel results. First, R&D subsidies not only encourage innovation but also boost subsequent expansion investment. R&D subsidies are an important pillar of innovation policy in many countries, see OECD (2008), and Bloom, Griffith and Van Reenen (2002) for empirical evidence how a reduction in R&D costs stimulates R&D. In contrast to the existing literature which emphasizes innovation spillovers as a rationale for R&D subsidies, the welfare gains in our model derive from the fact that the subsidy relaxes finance constraints and allows firms with an excess return to exploit investment opportunities to a larger extent. Second, taxes which are neutral in a neoclassical world, still restrict expansion investment of constrained firms by reducing free cash-flow and thereby discourage innovation. Third, a revenue neutral increase in profit taxes to finance larger R&D subsidies redistributes towards innovative firms and boosts aggregate productivity and welfare. Fourth, a revenue neutral tax cut cum base broadening policy similarly boosts innovation and welfare.

Existing literature in public economics has analyzed the implications of tax policy for entrepreneurship and entry in the presence of asymmetric information.[2] The present paper, in contrast, focusses on discrete innovation choice and subsequent expansion in-

[2]For highly selective references to business taxation under asymmetric information, see Stiglitz and Weiss (1981), De Meza and Webb (1987), Fuest and Tillessen (2005) and the synthesis of Boadway and Keen (2006) on the effects of taxes on adverse selection and entry, and Keuschnigg and Nielsen (2004a,b) on entrepreneurship with moral hazard.

vestment of firms. More recently, Chetty and Saez (2009) and Koethenbuerger and Stimmelmayr (2009) also consider the implications of agency costs on the scale of investment but take an alternative approach. These papers focus on the role of dividend and corporate taxes when managers make inefficient investment choices by diverting funds to 'pet' projects which do not generate income and yield utility (private benefits) only to managers but not to shareholders.[3] Similarly, studying theft by company insiders, Desai, Dyck, and Zingales (2007) show that corporate taxes may lead to more theft and diversion of funds (see also the survey in Desai and Dharmapala, 2008, on the interaction of tax systems and corporate governance). In these papers, the agency problem is to prevent the misuse of company funds. We believe that these theories are more descriptive of the behavior of large unconstrained firms with free cash-flow that may be misused by corporate insiders. Our approach, instead, focusses more on the role of finance constraints for investment of growth companies that are unable to invest up to the efficient scale because they have difficulty in raising external funds. To the best of our knowledge, our paper is unique in explaining the coexistence and endogenous composition of constrained and unconstrained firms as a result of a discrete innovation decision.

The paper proceeds as follows. Section 2 introduces the model. Section 3 derives comparative static results and prepares Section 4 which presents the main results on the impact of taxes and subsidies in a finance constrained economy. Section 5 concludes.

2 The Model

2.1 Overview

There is a mass 1 of risk-neutral agents, each endowed with initial assets A per capita. A fixed fraction E of the population is endowed with entrepreneurial ability and one

[3] Allocating funds to unproductive pet projects eats up resources and reduces corporate earnings. In our model, banks' credit decisions prevent that entrepreneurs enjoy private benefits in equilibrium so that all resources are productively used.

investment project. Entrepreneurs are heterogeneous in the sense that the early stage success probability $q' \in [0,1]$ of their project may be high or low. With probability $1-q'$, the project fails and the firm is closed down. The distribution of entrepreneurs with projects of type q' is given by $G(q') = \int_0^{q'} g(\tilde{q})\,d\tilde{q}$. An entrepreneur earns an expected profit or surplus π_E, giving end of period wealth $\pi_E + AR$. For entrepreneurship to be worthwhile, end of period wealth must at least compensate foregone earnings AR from an alternative capital market investment where r is a safe deposit rate of interest, and $R \equiv 1+r$. The remaining part $1-E$ of agents have no managerial ability and can only invest assets on a deposit market, giving end of period wealth and consumption equal to AR. The deposit rate is fixed on international capital markets.[4]

Preferences are linearly separable in consumption equal to end of period wealth after taxes, plus possibly a transfer received from the government, plus the value of leisure or 'private benefits'. Managerial misbehavior will be prevented by incentive compatible lending conditions so that private benefits are not consumed in equilibrium. End of period utility of an investor is $v_N = AR$ while entrepreneurs enjoy per capita expected utility equal to $v_E = AR + T_E + \pi_E$, where expected net profit π_E is net of taxes, and T_E is a per capita transfer. Only entrepreneurs invest and are subject to taxes. To isolate the excess burden from profit taxation and avoid any redistributive issues, we assume that tax revenue is refunded to entrepreneurs only.

Value maximizing involves several choices during a firm's life-cycle. At an early stage, firms decide whether or not to undertake a fixed R&D investment k with private cost $(1-\sigma)\,kR$ where σ is an R&D subsidy and R converts into end of period value. Our assumptions below imply that innovating firms will be finance constrained, indicated by an index $j=c$, while standard firms are unconstrained (index $j=u$). Hence, private R&D spending of a type j firm is $k_j \in \{0, (1-\sigma)\,kR\}$. Innovation has two consequences. First, R&D spending drains own resources and leaves residual assets $A_j = A - k_j$, where

[4] An alternative interpretation is that R is a fixed productivity of a safe Ricardian technology which converts one unit of the good at the beginning of period into R units at the end of period.

$A_c < A_u = A$. Second, innovation raises a firm's productivity from $\theta_u = 1$ to $\theta_c = \theta > 1$ and leads them to invest at a larger scale, $I_c > I_u$. For both reasons, innovating firms require a larger credit, assuming that expansion investment exceeds own funds. Hence, a firm's productivity determines net output $x_j = \theta_j f(I_j)$ from the concave production technology $f' > 0 > f''$. However, expansion investment is risky and may succeed with a high or low probability, $p > p_L$. A high success probability is possible only with full effort of the entrepreneur, while shirking (consuming private benefits) results in more frequent failure and a lower survival probability. Hence, expansion investment yields output x_j with probability p if effort is high, and nothing when the firm fails with probability $1-p$. Given higher productivity, innovating firms invest at a larger scale and are more profitable, leading to expected net of tax profits $\pi_c > \pi_u$.

The timing of events is: (i) Project type q' is revealed; (ii) Depending on q', the firm decides on R&D; (iii) If the early stage is successfully completed, the firm chooses expansion investment I_j and must raise the required credit $D_j = I_j - A_j$; (iv) The entrepreneur chooses managerial effort, leading to p when effort is high, or p_L when private benefits are enjoyed; (v) The firm produces output and pays back credit if investment is successful. The model is solved by backward induction.

Ex ante, entrepreneurs might have a project of any possible type q'. Only good projects $q' > q$ warrant R&D to obtain a higher productivity and larger net present value $\pi_c q' - k_c$. Other firms with low quality projects $q' < q$ do not innovate, avoid R&D spending, and get only a smaller expected value $\pi_u q'$. Hence, expected net profits ex ante are

$$\pi_E = \int_0^1 \left[\pi(q')\, q' - k(q')\right] dG(q') = \int_0^q \pi_u q' dG(q') + \int_q^1 \left[\pi_c q' - k_c\right] dG(q'). \tag{1}$$

Once the early stage investment risk is resolved, firms are fully symmetric within each group but differ across innovation status.

2.2 Investment and Innovation

When the early stage is successful, the firm enters the expansion phase and chooses investment. Innovative firms have large investment opportunties but are left with little own assets due to prior R&D spending. Hence, they need a large credit $D_c = I_c - A_c$.[5] Standard firms with low productivity optimally invest at a smaller scale, have undiminished own resources and need a small credit. Since own equity is predetermined and investment is variable, the marginal source of finance is debt. The loan rate for risky business debt is $i > r$. The government taxes profit at the rate τ but allows deduction of a share λ of total financing costs iI_j. The tax liability is $T_j = \tau (x_j - \lambda i I_j)$ if the firm survives the expansion stage. Net of the R&D subsidy, the total end of period value of an innovating firm's tax liability is $T_c - \sigma k R$ if it is successful in all stages. Setting $\lambda = 1$ and $\sigma = \tau$, the system is equivalent to an ACE system.[6] The expected profit (or surplus over residual assets A_j) of an entrepreneur with a type j firm is

$$\begin{aligned} \pi_j^e &= p\left[I_j + x_j - (1+i) D_j - T_j\right] - RA_j, \\ \pi_j^b &= p(1+i) D_j - RD_j = 0, \\ \pi_j &= p(I_j + x_j - T_j) - RI_j. \end{aligned} \tag{2}$$

We assume perfect competition on the external capital market. Hence, in equilibrium, the competitive loan rate is determined by the zero profit condition $p(1+i) = R$. Expected repayment covers the bank's refinancing cost on the deposit market. To cover the losses from credit default, the loan rate must exceed the safe deposit rate. Given that banks make

[5] We phrase external funding in terms of debt. In this simple two state model, new debt and new equity are, in fact, equivalent in the absence of tax so that D_j could also be interpreted as new equity. However, if there is a tax advantage of debt, agents would strictly prefer debt over equity.

[6] In reality, most often only interest on debt is deductible. The tax liability would be $\tau (x_j - iD_j)$ since the opportunity cost iA_c of equity is not eligible for a deduction. We choose the current formulation partly for simplicity but also to emphasize that even a 'neutral' tax discourages investment of constrained firms even if it doesn't affect the user cost. Alternatively, we could have assumed a cash-flow tax. The results in Keuschnigg and Ribi (2009) imply that ACE and cash-flow taxes are equivalent but not neutral.

zero profits, the entrepreneur appropriates the entire joint surplus of the firm, $\pi_j^e = \pi_j$. Define the user cost of capital u and write expected net of tax profit of a type j firm as

$$\pi_j = (1-\tau)\, p\,(x_j - uI_j)\,, \quad u \equiv \frac{1-\lambda\tau}{1-\tau} \cdot i. \tag{3}$$

With an ACE system, the tax has no impact on the user cost, $\lambda = 1$ implies $u = i$.

Given innovation and investment choices at earlier stages, and a level of external debt, the entrepreneur will obtain a surplus $v_j^e \equiv I_j + x_j - (1+i)\,D_j - T_j$ if the firm survives. If she works hard, the success probability and expected income pv_j^e will be high. Alternatively, shirking results in a low survival probability $p_L < p$ and a low expected income $p_L v_j^e$, but the entrepreneur can enjoy private benefits bI_j. The incentive compatibility condition for high effort is

$$IC^e: \quad pv_j^e \geq p_L v_j^e + bI_j \quad \Leftrightarrow \quad v_j^e \geq \beta I_j, \quad \beta \equiv b/\,(p-p_L)\,. \tag{4}$$

Incentive compatibility is assured only if the entrepreneur keeps a minimum stake $v_j^e \geq \beta I_j$ in the firm so that the increase in expected income as a return to effort exceeds the foregone private benefits from shirking. To assure high effort, the level of investment and, therefore, the size of external debt must not exceed the firm's pledgeable income, $(1+i)\,D_j \leq I_j + x_j - T_j - \beta I_j$. Since we want to focus on equilibria where innovative firms are credit constrained and standard firms are not, we impose the following assumption:

Assumption 1 *(i) At I_u given by $f'(I_u) = u$, the constraint is slack, $v_u^e(I_u) > \beta I_u$. (ii) At I_c given by $\theta f'(I_c) = u$, the incentive constraint is violated, $v_c^e(I_c) < \beta I_c$.*

Assumption (i) means that standard firms are unconstrained. In maximizing expected end of period wealth $\pi_u^e = pv_u^e - AR$, standard firms expand until the return on investment is equal to the user cost of capital,

$$f'(I_u) = u, \quad u \equiv \frac{1-\lambda\tau}{1-\tau} \cdot i. \tag{5}$$

Innovative firms have less internal assets, $A_c = A - (1-\sigma)\,k$, but higher productivity $\theta > 1$ than standard firms. Part (ii) of the above assumption means that they are constrained and can not fully exploit their growth potential. Investment is constrained by the incentive compatibility condition,

$$v_c^e = \beta I_c, \quad v_c^e = (1-\tau)\left[\theta f(I_c) - uI_c\right] + (1+i)A_c. \tag{6}$$

Since $\pi_j^e = pv_j^e - A_jR = \pi_j$, we multiply by p, rewrite the constraint as $\pi_j \geqslant p\beta I_j - A_jR$ and illustrate in Figure 1 where unconstrained values are marked by a star.

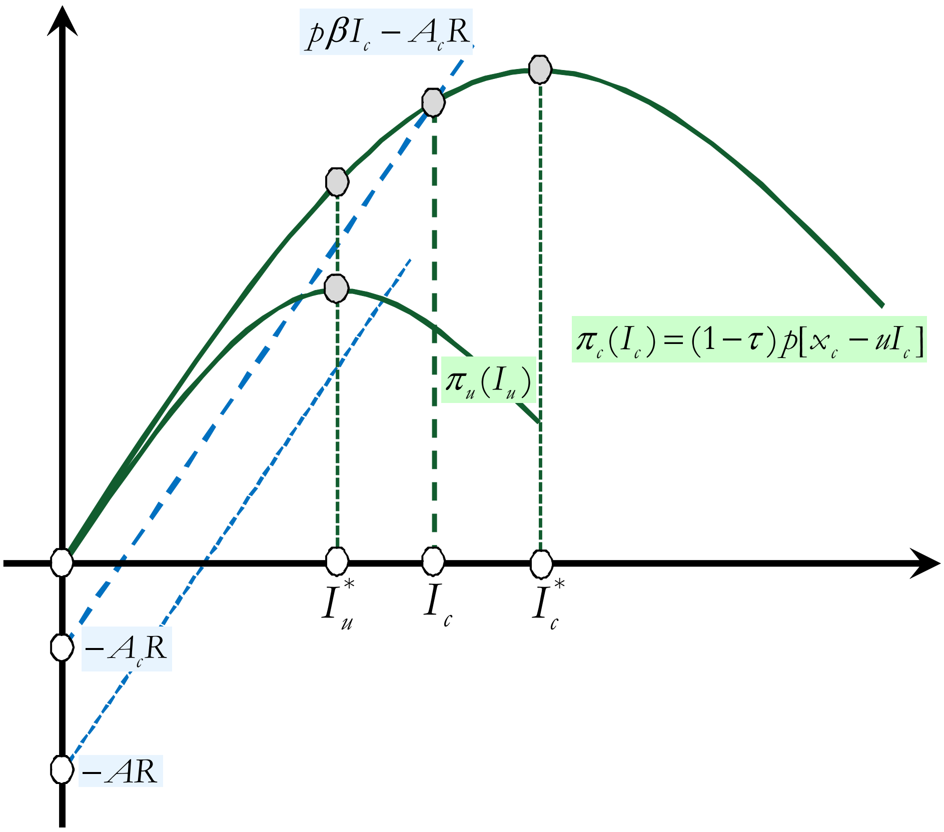

Fig. 1: Incentive Compatible Investment

At any investment level, expected profit of innovative firms is larger since they are more productive as a result of prior R&D ($\theta > 1$). Standard firms invest until expected profit is at a maximum. They have undiminished wealth A so that the line $p\beta I_u - AR$ starts out at $-AR$. Clearly, at the optimal investment level I_u^*, the incentive constraint is slack, $\pi_u(I_u^*) > p\beta I_u^* - AR$. If innovative firms had no financing problem, they would invest I_c^* to maximize expected profit. However, banks would deny the required funding. They anticipate that a debt obligation of this size would violate the entrepreneur's incentive constraint so that the loan would be repaid only with a lower probability $p_L < p$ and the bank could not break even with the competitive loan rate i. The firm is able to raise credit only up to $I_c - A_c$ and can invest no more than $I_c < I_c^*$ where the incentive constraint is just binding in Figure 1.[7]

The choice of expansion investment results in profits that firms can expect conditional on the level of R&D investment. As Figure 1 illustrates, R&D leads to higher profits but comes at an additional fixed cost. Firms must decide on their innovation strategy before the development risk is resolved. They differ by the quality of their business idea which is reflected in a given probability q' of successfully completing the start-up phase. With probability $1 - q'$, the firm fails and closes down. Any R&D investment is lost. Firms of type q' invest in R&D if $q'\pi_c - (1-\sigma) kR \geq q'\pi_u$, giving the cut-off value

$$q = \frac{(1-\sigma) kR}{\pi_c - \pi_u} < 1. \tag{7}$$

Firms with better projects $q' > q$ invest in R&D, less promising ventures do not. Figure 2 illustrates. At the date of entry when firms have not yet learned the nature of their project but know only the distribution of possible types, expected profit is given by (1). Anticipating subsequent innovation and investment decisions yields

$$\pi_E = s_u\pi_u + s_c\pi_c - s_k (1-\sigma) kR > 0, \tag{8}$$

where the ex ante probabilities of innovation s_k and of surviving the start-up phase s_c and s_u are defined as

$$s_u = \int_0^q q' dG(q'), \quad s_c = \int_q^1 q' dG(q'), \quad s_k = \int_q^1 dG(q'). \tag{9}$$

Expected profit $\pi_E = \int_0^1 \pi_u q' dG(q') + \int_q^1 [(\pi_c - \pi_u) q' - (1-\sigma) kR] dG(q')$ is positive since the square bracket is zero at the cut-off but strictly positive for better types. All

[7] If the firm asked for a marginally larger credit, banks could still provide credit by discretely raising the loan rate to $i_L > i$ until $(1 + i_L) p_L = R$. Profit v_c^e would marginally rise if i were not changed but falls discretely if the loan rate rises to i_L. We must assume p_L low enough so that firms do not prefer discretely larger credit $I_c^* - A_c$ at i_L. An equilibrium with shirking is definitely not viable if $p_L \to 0$.

potential entrepreneurs strictly prefer entry and invest their wealth A in their own firm rather than in the capital market. Out of E start-up firms, only a part $s_k E$ invest in R&D and only $s_j E$ survive the start-up phase. Out of these, a fraction $1 - p$ fails in the expansion stage, and only a part $ps_j E$ makes it to the production stage. Appendix A states conditions that assure an interior solution.

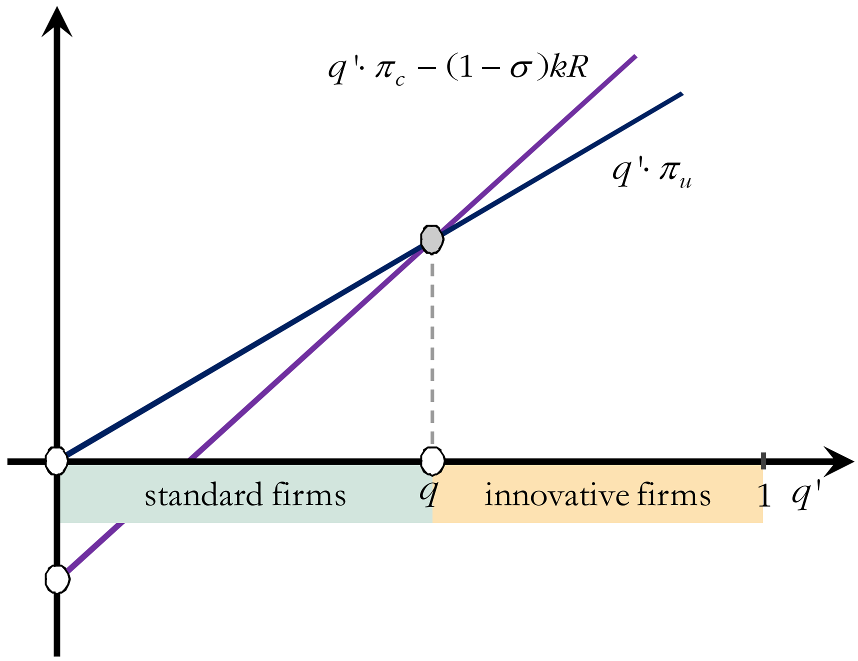

Fig. 2: Innovation Decision

2.3 General Equilibrium

The government collects taxes from firms and could use it for public goods or redistributive transfers. Since the aim of this study is to isolate the efficiency implications of profit taxation in the presence of finance constraints, we assume here that tax revenues are refunded back to firms. At the same time, we assume that these transfers are received in the private sphere and cannot be pledged to banks to raise larger credit. This assumption is meant to reflect the fact that, in reality, firms do not receive lump-sum transfers from the government but only for specific purposes such as R&D subsidies or infrastructure. Hence, the entrepreneur's expected end of period utility is $v_E = AR + \pi_E + T_E$. Aggregate tax revenue amounts to $T_E E$, or T_E per firm,

$$T_E = \sum_j ps_j T_j - \sigma s_k kR, \quad T_j = \tau (x_j - \lambda i I_j). \tag{10}$$

Appendix B states the equilibrium conditions on deposit and output markets. Given a fixed deposit rate, these conditions are not relevant for further analysis.

3 Comparative Static Analysis

To prepare for the discussion of tax reform, this section develops the comparative statics of the model. The notation denotes relative changes, e.g. $\hat{I}_j \equiv dI_j/I_j$. The usual exceptions are the change in tax rates $\hat{\tau} \equiv d\tau/(1-\tau)$ and $\hat{\sigma} \equiv d\sigma/(1-\sigma)$. We evaluate all tax changes starting from an equilibrium with an ACE tax in place, $\lambda = 1$ and $\sigma = \tau$, implying a user cost $u = i$. This assumption not only much simplifies calculations but also helps to focus on the non-standard effects of tax policy where taxes work not via the user cost channel but via cash-flow sensitivity of constrained firms. In considering base broadening policies, we restrict deductions by setting $\hat{\lambda} = d\lambda < 0$ in some scenarios.

3.1 Investment and Profits

Given a constant deposit rate, competition among banks fixes the loan rate i via the zero profit condition $(1+i)\,p = R$. Investment of standard firms responds by (see 5),

$$\hat{I}_u = u_\lambda \cdot \hat{\lambda}, \quad u_\lambda \equiv \frac{\tau}{1-\tau}\frac{1}{1-\alpha}, \quad -\frac{f'(I_j)}{I_j f''(I_j)} = \frac{1}{1-\alpha} > 1. \tag{11}$$

In starting from $\lambda = 1$ and $u = i$, a larger tax rate does not affect the user cost and has no impact on investment. By the envelope theorem, profit of a standard firm changes by

$$d\pi_u = -\pi_u \cdot \hat{\tau} + \tau i p I_u \cdot \hat{\lambda}. \tag{12}$$

Base broadening ($\hat{\lambda} < 0$) discourages investment while a tax cut ($\hat{\tau} < 0$) has no effect since the tax is neutral in the initial equilibrium. While the tax cut obviously strengthens expected net of tax profit, base broadening reduces it.

Given that innovative firms are constrained, investment is determined by the incentive constraint in (6) where the entrepreneur's residual income in the good state after repaying debt is $v_c^e = (1-\tau)\,\theta f\,(I_c) - (1-\lambda\tau)\, iI_c + (1+i)\,[A-(1-\sigma)\,k]$. In taking the differential, we evaluate at $\lambda = 1$, measure the tightness of the finance constraint by the excess return $\rho \equiv (1-\tau)\,(x_c' - i)$, and use $\pi_c = (1-\tau)\,p\,(x_c - iI_c)$ initially,

$$\hat{I}_c = -\frac{\pi_c}{mI_c} \cdot \hat{\tau} + \frac{\tau i p I_c}{mI_c} \cdot \hat{\lambda} + \frac{(1-\sigma)\,kR}{mI_c} \cdot \hat{\sigma}, \quad m \equiv (\beta - \rho)\,p < R. \tag{13}$$

Assumption $m < R$ guarantees positive leverage of own assets, $dI_c/dA > 1$.

If the firm were unconstrained, the investment response would be analoguous to (11). To compare to the unconstrained case, we rewrite (13) as

$$\hat{I}_c = -\phi_\tau \cdot \hat{\tau} + (u_\lambda + \phi_\lambda) \cdot \hat{\lambda} + \phi_\sigma \cdot \hat{\sigma}, \tag{14}$$

where the ϕ-coefficients are defined as

$$\phi_\tau \equiv \frac{\pi_c}{mI_c}, \quad \phi_\lambda \equiv \frac{\tau i p}{m} - u_\lambda \gtrless 0, \quad \phi_\sigma \equiv \frac{(1-\sigma)\,kR}{mI_c}.$$

Setting $\phi_\tau = \phi_\lambda = \phi_\sigma = 0$ yields the unconstrained case where $\hat{I}_c = u_\lambda \hat{\lambda}$ and neither the tax nor the subsidy rate, τ and σ, affect expansion investment. In this case, the tax rate is neutral when an ACE system is in place, and the subsidy on fixed R&D spending doesn't affect the user cost of investment. When innovative firms are finance constrained, investment becomes sensitive to cash-flow. The tax rate reduces future cash-flow and thereby erodes the firm's pledgeable income while the subsidy strengthens residual own equity A_c after R&D spending. Both a tax cut and a higher subsidy boost the firm's financing capacity and thereby facilitate investment. Note that there is no clear-cut argument to sign ϕ_λ, meaning that the effect of λ may be stronger or weaker than in the unconstrained case. However, the net effect is clearly positive, as the comparison with (13) shows. Broadening the tax base by restricting interest deductions inflates the firm's tax liability and reduces investment by draining future cash-flow and pledgeable income.

Starting with $\lambda = 1$, the expected profit in (2.2) changes by

$$d\pi_c = -\pi_c \cdot \hat{\tau} + \tau i p I_c \cdot \hat{\lambda} + \rho p I_c \cdot \hat{I}_c. \tag{15}$$

The first two terms are structurally identical to (12). However, when investment is constrained, the envelope theorem does not apply anymore so that larger investment boosts profits. The impact on profit is proportional to the excess return $\rho > 0$ which measures the tightness of the finance constraint. We summarize:

Proposition 1 ***(Excess Return)*** *Financially constrained firms earn a return on investment in excess of the user cost of capital. Expanding investment raises the joint surplus π_c in the expansion stage.*

3.2 Innovation, Productivity and Firm Value

Prior to expansion investment, firms decide on the (discrete) innovation strategy. R&D raises future productivity but also drains the firm's financial resources. The return to innovation consists of the anticipated increase in future profit, but accrues only if a firm actually survives. When it fails, the R&D investment is lost. In consequence, innovation is profitable only for those firms with the highest survival chances. The cut-off value q changes by $\hat{q} = -\frac{d\pi_c - d\pi_u}{\pi_c - \pi_u} - \hat{\sigma}$. Inserting profit changes from (12) and (15) and substituting the investment response of constrained firms from (14) yields

$$\hat{q} = \zeta_\tau \cdot \hat{\tau} - \zeta_\lambda \cdot \hat{\lambda} - \zeta_\sigma \cdot \hat{\sigma}, \tag{16}$$

where elasticities are defined to be positive,

$$\zeta_\tau \equiv 1 + \frac{\rho p I_c \phi_\tau}{\pi_c - \pi_u}, \quad \zeta_\lambda \equiv \frac{\tau p i \left(I_c - I_u\right) + \rho p I_c \left(u_\lambda + \phi_\lambda\right)}{\pi_c - \pi_u}, \quad \zeta_\sigma \equiv 1 + \frac{\rho p I_c \phi_\sigma}{\pi_c - \pi_u}.$$

Obviously, R&D tax credits (or subsidies) boost innovation. Since innovative firms are more productive, earn larger profits and invest at a larger scale, a higher tax rate reduces the share of innovating firms by raising the innovation threshold. Restricting tax deductions ($\hat{\lambda} < 0$) triggers the same impact. The innovation response would be qualitatively the same even if innovative firms were not constrained (set $\rho = 0$ in the elasticities). Finance constraints merely magnify the response.

Innovation boosts productivity. There are $s_c pE$ highly productive, innovative firms in the total pool $(s_c + s_u) pE$, resulting in average productivity $\theta_E = \frac{s_c}{s_c+s_u}\theta + \frac{s_u}{s_c+s_u}$. Since $s_c + s_u$ is a constant, the composition of firms changes by $ds_c = qds_k = -ds_u = -q^2 g(q)\hat{q}$, see (9). If more firms innovate ($\hat{q} < 0$), average productivity rises by

$$d\theta_E = -(\theta - 1)\frac{q^2 g(q)}{s_c + s_u} \cdot \hat{q}. \tag{17}$$

For a complete welfare analysis of tax policy, one must know the impact on the net present value π_E of a new firm and on the total net tax liability T_E per entrant. Taking the differential of (8), expected profit changes by $d\pi_E = \sum_j s_j d\pi_j + (1-\sigma) s_k kR\hat{\sigma}$ where $\pi_u ds_u + \pi_c ds_c - (1-\sigma) kRds_k = [(\pi_c - \pi_u) q - (1-\sigma) kR] ds_k = 0$ follows when using $ds_c = qds_k = -ds_u$. A rising cut-off q implies fewer innovating firms and lower productivity. However, on account of innovation choice in (7), a marginal change in firm composition does not affect expected total profit of a new firm. Substituting (12), (14) and (15) and defining $\bar{\pi} \equiv s_c\pi_c + s_u\pi_u$ as well as $\bar{I} \equiv s_c I_c + s_u I_u$ yields

$$\begin{aligned} d\pi_E &= -(\bar{\pi} + \rho p s_c I_c \phi_\tau) \cdot \hat{\tau} + \tau p i \left(\bar{I} + \rho p s_c I_c / m\right) \cdot \hat{\lambda} \\ &: \quad + ((1-\sigma) s_k kR + \rho p s_c I_c \phi_\sigma) \cdot \hat{\sigma}. \end{aligned} \tag{18}$$

The profit elasticities are magnified by the excess return ρ of constrained firms.

The expected net tax liability is $T_E = \sum_j s_j pT_j - \sigma kRs_k$ where expected tax pT_j of a type j firm changes by (use $\lambda = 1$ and $\rho_j = (1-\tau)\left(x_j' - i\right)$ with $\rho_u = 0$ and $\rho_c = \rho$)

$$pdT_j = \pi_j \cdot \hat{\tau} - \tau p i I_j \cdot \hat{\lambda} + \frac{\tau}{1-\tau} p\rho_j I_j \cdot \hat{I}_j. \tag{19}$$

Using $ds_u = q^2 g(q)\hat{q} = -ds_c = -qds_k$, total net tax T_E changes by

$$dT_E = \sum_j s_j \cdot pdT_j - (1-\sigma) kRs_k \cdot \hat{\sigma} - \nabla_T qg(q) \cdot \hat{q}, \quad \nabla_T \equiv p(T_c - T_u) q - \sigma kR,$$

where ∇_T is the change total tax liability when a marginal firm switches the innovation mode. Substituting (19) and noting $\rho_u = 0$ yields

$$dT_E = \bar{\pi} \cdot \hat{\tau} - \tau p i \bar{I} \cdot \hat{\lambda} - (1-\sigma) kRs_k \cdot \hat{\sigma} + \frac{\tau}{1-\tau} p\rho s_c I_c \cdot \hat{I}_c - \nabla_T qg(q) \cdot \hat{q}. \tag{20}$$

The first three terms are the direct, mechanical effects of policy on expected tax revenue per firm. The last two terms reflect behavioral responses which will be substituted later, depending on the specific scenario.

Finally, subsequent analysis will need to sign the term ∇_T when an ACE tax is in place ($\lambda = 1$ and $\sigma = \tau$). With an ACE tax, gross profits $\pi_j^* = p(x_j - iI_j)$ are related to net of tax profits by $\pi_j = (1-\tau)\pi_j^*$. Expected tax liability is $pT_j = \tau\pi_j^*$. The innovation cut-off becomes $(1-\tau)(\pi_c^* - \pi_u^*) q = (1-\tau) kR$. Hence, in an equilibrium with an arbitrary tax rate and an ACE system, the term $(\pi_c^* - \pi_u^*) q$ is fixed at kR, leaving

$$\nabla_T = p(T_c - T_u) q - \tau kR = \tau(\pi_c^* - \pi_u^*) q - \tau kR = 0. \tag{21}$$

With an ACE system, the change in expected tax liability when a marginal firm switches from innovation to the standard technology, is zero. Irrespective of how gross profits π_j^* change, the cut-off q must move in a compensating way so that the innovation condition remains fulfilled.

4 Tax Policy and Financial Dependence

4.1 Introducing an R&D Tax Credit

We first consider the implications of an R&D tax credit, i.e. a subsidy to private R&D spending. To isolate the efficiency effects, we assume that the subsidy is financed by a lump-sum tax T_E (negative transfers) at the end of the period. To be lump-sum, it must not affect lending decisions of banks and effort choice of entrepreneurs. We thus assume that this tax is paid in the 'private sphere' and does not affect pledgeable income of the firm.[8] In any case, the scenario is meant to isolate the efficiency effects of the subsidy and

[8] Alternatively, the tax could be imposed on investors who cannot avoid it. It would reduce their welfare to $v_N = AR - T_N$, with fiscal balance requiring $ET_E + (1-E) T_N = 0$. To isolate efficiency gains, one would consider the change in aggregate welfare $V = Ev_E + (1-E) v_N$.

to clarify the consequences when firms are finance constrained. We also assume $\tau = 0$ in this subsection and turn to self-financed R&D subsidies in the following subsections.

The R&D subsidy is irrelevant for standard firms which do not spend on R&D. Both investment and profits at the expansion stage remain constant, $\hat{I}_u = d\pi_u = 0$. However, the subsidy has interesting and non-trivial implications for the expansion stage of innovative firms. The key insight is that R&D spending at an early stage drains internal resources that are needed to self-finance part of subsequent expansion investment. The subsidy thus relaxes the financing constraint. By (14-16),

$$\hat{I}_c = \phi_\sigma \cdot \hat{\sigma} > 0, \quad d\pi_c = \rho p I_c \phi_\sigma \cdot \hat{\sigma} > 0, \quad \hat{q} = -\zeta_\sigma \cdot \hat{\sigma} < 0. \tag{22}$$

By strengthening internal funds, the subsidy allows for more self-financing and additional external leverage of expansion investment. In other words, the R&D subsidy not only encourages R&D activity but also helps firms to exploit the new investment opportunities to a larger extent. This novel role of R&D tax credits also boosts profits in the expansion stage in proportion to the excess return ρ on constrained investment. This profit gain would not be present if firms were unconstrained. In that situation, investment would be expanded until the marginal return equals the user cost of capital so that the excess return would be zero. Another consequence of the R&D subsidy is that a larger profit of an innovative firm in the expansion stage reinforces the firm's incentives to engage in R&D. This extra profit gain reduces the innovation threshold q beyond the direct effect of an R&D subsidy. Noting the elasticity $\zeta_\sigma = 1 + \rho p I_c \phi_\sigma / (\pi_c - \pi_u)$, the direct effect $\hat{q} = -\hat{\sigma}$ is magnified by the increased profitability of innovation when the firm is able to exploit subsequent growth opportunities to a larger extent. In consequence, average factor productivity θ_E in (17) rises when more firms innovate.

An R&D subsidy yields a first order welfare gain even if the subsidy is small. The welfare gain arises not because of knowledge spillovers as is traditionally argued. The present model excludes external effects of R&D. The gains arise because the subsidy relaxes the finance constraint and thereby allows innovative firms to invest more at an above average, excess return which raises aggregate income. To verify this, read the changes in expected profit and required tax revenue to pay for the subsidy from (18) and (20). Note that the differential budget cost of one more firm choosing to innovate is $\nabla_T = -\sigma kR$ as long as the profit tax rate is zero. Hence, using (22),

$$\begin{aligned} d\pi_E &= [(1-\sigma)\, kRs_k + \rho ps_c I_c \phi_\sigma] \cdot \hat{\sigma}, \\ dT_E &= -[(1-\sigma)\, kRs_k + \sigma kRqg\,(q)\,\zeta_\sigma] \cdot \hat{\sigma}. \end{aligned} \tag{23}$$

The subsidy boosts profits not only directly by subsidizing private R&D costs but also indirectly, in proportion to the excess return ρ, by stimulating expansion investment. The direct tax cost of subsidizing R&D of all innovating firms is $dT_E = -(1-\sigma)\, kRs_k\hat{\sigma}$. Since the subsidy reduces the innovation threshold q, the government must subsidize even *more new* innovators at an extra budget cost of $dT_E = \sigma kR \cdot qg\,(q)\,\hat{q} < 0$.

Welfare of investors and entrepreneurs is $v_N = AR$ and $v_E = AR + \pi_E + T_E$, respectively, which yields a utilitarian welfare measure $V = Ev_E + (1-E)\, v_N$. Since investors are not affected in our scenario, welfare changes in proportion to dv_E. Adding up the two components in (23) shows that net welfare rises by

$$dv_E = d\pi_E + dT_E = [\rho ps_c I_c \phi_\sigma - \sigma kR \cdot \zeta_\sigma \cdot qg\,(q)] \cdot \hat{\sigma}. \tag{24}$$

In the present model, knowledge spillovers and other external effects of innovation are exluded by assumption. When finance constraints are not binding ($\rho = \phi_\sigma = 0$ and $\zeta_\sigma = 1$), firms expand investment until the marginal return is equal to the user cost of capital. Any possible excess return is fully eliminated in equilibrium. Innovation would be Pareto optimal. Consequently, the optimal subsidy would be zero. Any positive one would only introduce an excess burden so that welfare would decline in proportion to the subsidy rate, $dv_E = -\sigma kR\zeta_\sigma qg\,(q)\,\hat{\sigma}$. In contrast, if innovative growth companies, characterized by small own resources and large investment opportunities, are finance constrained, a subsidy payment of value σkR boosts pledgeable income and allows firms to expand investment, not only because of larger own resources but also because of more external funds. In better exploiting investment opportunities from innovation, these firms generate additional net income to society where the profit gains are proportional to the excess return $\rho = x_c' - i$. Clearly, it is welfare improving to introduce a small subsidy starting from $\sigma = 0$, $dv_E = \rho p s_c I_c \phi_\sigma \hat{\sigma} > 0$. As the rate becomes positive and more firms innovate to capture the subsidy, the standard excess burden kicks in. Further raising the subsidy becomes ever more costly. Apart from the preexisting size of the subsidy, the excess burden depends on the magnitude of the innovation elasticity ζ_σ and the mass of firms $g(q)$ which are switching to new R&D activity. In the absence of other policies, the subsidy would be optimal when the marginal welfare gain in (24) is zero, i.e. $\rho p s_c I_c \phi_\sigma = \sigma k R \cdot \zeta_\sigma \cdot q g(q)$ holds. With an optimal subsidy, the marginal gains from relaxing finance constraints is balanced by the excess burden. To sum up, we state:

Proposition 2 ***(R&D Subsidy)*** *An R&D subsidy (i) boosts innovation and augments the share of constrained firms; (ii) stimulates investment and profit of constrained firms; and (iii) a small subsidy yields first order welfare gains.*

4.2 Profit Taxation

To highlight the impact of tax reform on innovation and, thus, on capital investment of more or less profitable firms, we first study the consequences of introducing an ACE tax which is defined by $\lambda = 1$ and $\sigma = \tau$. In extending the ACE system to include a full tax deduction of innovation costs, the tax would be fully neutral in an unconstrained equilibrium, not only with respect to equipment investment but also with respect to the innovation choice.[9] Thus, our scenario yields a clear benchmark to isolate the implications of finance constraints. Since we want to focus on efficiency effects, we follow the approach in the preceding subsection and refund revenues as transfers T_E to entrepreneurs.

Raising the tax rate $\hat{\tau} = \hat{\sigma}$ and keeping $\lambda = 1$ does not impair investment of standard, unconstrained firms, $\hat{I}_u = 0$, since the tax is neutral with respect to the user cost of capital, $u = i$. However, being a tax on rent, it squeezes net of tax profits by $d\pi_u = -\pi_u \hat{\tau}$. In contrast, the tax not only reduces profits of innovative firms but also investment which

[9] ACE and cash-flow taxes are equivalent in our framework, see Keuschnigg and Ribi (2009).

is sensitive to cash-flow. Restricting investment further erodes profits in proportion to the excess return ρ, see (15). For this reason, the tax discriminates against innovative and more profitable firms. As a consequence, innovation is discouraged and the share of constrained firms falls. Evaluating (16), we compute $\hat{q} = (\zeta_\tau - \zeta_\sigma)\,\hat{\tau}$ which gives

$$\hat{I}_c = -\left(\phi_\tau - \phi_\sigma\right) \cdot \hat{\tau} < 0, \quad \hat{q} = \rho p I_c \frac{\phi_\tau - \phi_\sigma}{\pi_c - \pi_u} \cdot \hat{\tau} > 0. \tag{25}$$

Given the condition for discrete innovation choice in (7), where $\sigma = \tau$ with an ACE tax, we clearly find a positive sign of $\phi_\tau - \phi_\sigma = \left[(1-q)\,\pi_c + q\pi_u\right] / \left(mI_c\right) > 0$. Hence, the tax further constrains investment of innovative firms and discourages innovation.

To arrive at welfare results, one must derive the change in expected tax revenue and profit. Noting $\nabla_T = 0$ with an ACE tax, see (21), substitute the investment response in (20) and use $\pi_E = \bar{\pi} - (1-\sigma)\,kRs_k > 0$,

$$dT_E = \left[\pi_E - \frac{\tau}{1-\tau}\rho p s_c I_c \left(\phi_\tau - \phi_\sigma\right)\right] \cdot \hat{\tau}. \tag{26}$$

The last term reflects the loss in revenue when the tax further restricts investment and additionally reduces profit of constrained firms in proportion to the excess return. This behavioral effect would be zero in the absence of finance constraints (ϕ-coefficients and ρ would be zero). For the same reason, this part is absent for unconstrained firms since the tax does not affect the user cost. It is also absent when starting with a zero tax rate. At least for rates not too large, the tax raises revenue by taxing rents.

Finally, we evaluate the change in expected profits in (18)

$$d\pi_E = -\left[\pi_E + \rho p s_c I_c \left(\phi_\tau - \phi_\sigma\right)\right] \cdot \hat{\tau} < 0. \tag{27}$$

By the arguments above, the square bracket is clearly positive. The ACE system taxes rent and squeezes expected profits. Different from the standard case, the tax also constrains investment and thereby destroys unexploited profit opportunities as measured by the excess return ρ. It thus cuts into profits beyond the mere mechanical effect.

In the present scenario, the ACE tax is refunded to the entrepreneurial sector in order to isolate the efficiency effects. As in the preceding subsection, welfare changes in proportion to dv_E. Given the impact on net of tax expected profits and tax revenue, and noting $\rho = (1-\tau)(x'_c - i)$, the tax reduces net welfare in proportion to

$$dv_E = d\pi_E + dT_E = -(x'_c - i) \cdot ps_c I_c (\phi_\tau - \phi_\sigma) \cdot \hat{\tau} < 0. \tag{28}$$

The mechanical effect merely reflects redistribution from the entrepreneurial to the public sector and cancels in the aggregate. However, the behavioral effect strictly reduces welfare even if tax rates are zero initially! The reason is that even taxing rents tightens the financing constraint of innovative firms and further reduces investment which is already constrained in market equilibrium. In the presence of financing constraints, welfare is lower because of profitable but unexploited investment opportunities. Introducing even a small tax means that society loses even more income by further forfeiting profitable investments. The size of the welfare loss depends on the weight of innovative firms in the entire business sector, as indicated by $s_c I_c$. This welfare loss would not arise if none of the firms had any trouble in raising outside funds so that they would invest until the marginal return is equal to the user cost, $x'_c = i$. In summing up, we state

Proposition 3 ***(Profit Taxation)*** *The consequences of a higher rate of a profit tax which is neutral with respect to the user cost of capital, are: (i) the tax is neutral towards investment of standard firms but reduces investment of constrained firms; (ii) it reduces profits of constrained firms relatively more than profits of unconstrained firms and, thereby, discourages innovation; (iii) it leads to a first order welfare loss even for a small rate.*

The impact of the tax in an unconstrained economy where none of the firms is restricted in external funding, is easily recovered by setting the ϕ- and ρ-coefficients to zero. In this case, traditional theory suggests that the ACE tax is fully neutral. For example, investment of innovative firms in (14) would simply be $\hat{I}_c = u_\lambda \hat{\lambda}$. Neither the ACE tax rate τ, because it does not change the user cost, nor the upfront subsidy σ, because expansion investment is not sensitive to cash-flow, would have any impact on investment. Clearly, individual investments in (25) would be unaffected. Given that the mechanical effect reduces profits of standard and innovative firms as well as R&D costs by the same proportion, innovation would not affected either since the threshold q in (25) does not change. Consequently, the changes in tax revenue and private expected profit involve only mechanical effects which cancel and leave a zero impact on aggregate welfare. The tax is fully neutral in an unconstrained equilibrium.

4.3 Revenue Neutral Tax Reform

Starting from an initial equilibrium with an ACE system ($\tau = \sigma > 0$ and $\lambda = 1$, i.e. R&D spending and financing costs are fully deductible), the following subsections discuss a revenue neutral restructuring of profit taxation that boosts investment, productivity and welfare. Specifically, we will exogenously change λ or σ and compute revenue neutral changes in the tax rate to keep fiscal revenue constant. We show how these policies can be used to relax finance constraints by implicitly redistributing from standard to innovative but financially constrained firms.

4.3.1 Self-financed R&D Tax Credit

In reality, R&D spending on personnel etc. is tax deductible ($\sigma = \tau$), but governments often grant explicit additional subsidies, making $\sigma > \tau$. We show that this policy can potentially encourage private R&D spending and innovation based growth even if it is self-financed with a revenue neutral increase in the tax rate. The policy redistributes towards innovative firms since the higher tax rate extracts revenue from all firms while the subsidy is limited only to those with R&D spending. Set $dT_E = 0$ in (20) and note $\nabla_T = 0$ as in (21) when an ACE system is in place. Using the definition of ρ, the required increase in the tax rate is

$$\hat{\tau} = \epsilon_{\tau,\sigma} \cdot \hat{\sigma}, \quad \epsilon_{\tau,\sigma} \equiv \frac{(1-\sigma)\, kRs_k - \tau\,(x_c' - i)\, ps_c I_c \phi_\sigma}{\bar{\pi} - \tau\,(x_c' - i)\, ps_c I_c \phi_\tau} < 1. \tag{29}$$

Clearly, a higher R&D subsidy requires a higher tax rate to keep revenues constant. The tax rate needs to rise relatively less if the elasticity is smaller than one which is guaranteed if $\pi_E > \tau\left(x_c' - i\right) ps_c I_c \left(\phi_\tau - \phi_\sigma\right) > 0$. This condition is fulfilled when the tax rate is small, $\tau \to 0$, or if the finance constraint on innovative firms is weak, $\phi_j \to 0$. The preceding subsection showed that raising tax revenue with an ACE tax ($\hat{\tau} = \hat{\sigma}$) discriminated against innovative and financially constrained firms. By way of contrast, the revenue neutral restructuring of the profit tax in this subsection redistributes in the opposite direction. While the higher tax rate extracts revenue from all firms, the *disproportionate* increase in the subsidy favors innovative firms.

How does the policy affect investment, innovation and welfare? With an ACE system in place, the marginal reform is inconsequential for investment but squeezes profits of unconstrained firms, $\hat{I}_u = 0$ and $d\pi_u = -\pi_u \hat{\tau}$. For constrained firms, (14) implies

$$\hat{I}_c = \left(\phi_\sigma - \phi_\tau \epsilon_{\tau,\sigma}\right) \cdot \hat{\sigma} = \frac{\left(1-\sigma\right) kR - \pi_c \epsilon_{\tau,\sigma}}{mI_c} \cdot \hat{\sigma}. \tag{30}$$

Since $\pi_c - \left(1-\sigma\right) kR = \left(1-q\right) \pi_c + q\pi_u > 0$ by the innovation threshold, raising the ACE tax (case $\epsilon_{\tau,\sigma} = 1$) was seen to discriminate against innovative firms and reduce their investment. The present scenario, in contrast, may favor innovative firms and relax their financing constraint since the tax rate rises by a smaller amount. Hence, investment should become less constrained and expand if redistribution is strong enough,

$$\left(1-\sigma\right) kR - \pi_c \epsilon_{\tau,\sigma} > 0 \quad \Leftrightarrow \quad \chi\left(q\right) = \frac{\int_0^q q' dG\left(q'\right)}{\int_q^1 \left(1-q'\right) dG\left(q'\right)} = \frac{s_u}{s_k - s_c} > \frac{\pi_c^*}{\pi_u^*}. \tag{31}$$

To see this, get $\left(1-\sigma\right) kR - \pi_c \epsilon_{\tau,\sigma} = \left[\bar{\pi} - \pi_c s_k\right] \left(1-\sigma\right) kR / \left(\bar{\pi} - \tau\left(x_c' - i\right) ps_c I_c \phi_\tau\right)$. Note $\pi_j = \left(1-\tau\right) \pi_j^*$ which holds with an ACE system in place. Using also the definition of $\bar{\pi}$ yields $\bar{\pi} - \pi_c s_k = \left(1-\tau\right) \left[s_u \pi_u^* - \pi_c^* \left(s_k - s_c\right)\right]$. Hence, the numerator in (30) is positive if the condition in (31) holds. The numerator of χ reflects the average, early-stage *survival rate* of standard firms while the denominator refers to the average *failure rate* of innovating firms. In our model, innovating firms are more successful and survive to the market more frequently than firms with low productivity. Clearly, the ratio χ increases in the cut-off value q, $\chi'\left(q\right) > 0$. If innovation is costly, only few firms will innovate and the probability ratio becomes very large, $\lim_{q \to 1} \chi\left(q\right) = \infty$. For any given π_j, we may have a cost k such that the innovation threshold q, given by $\left(\pi_c^* - \pi_u^*\right) q = kR$ when an ACE system is in place, comes close to unity. Hence, an equilibrium with relatively few innovating and many standard firms implies a very large probability ratio so that the condition is certainly fulfilled. In this case, a higher R&D subsidy self-financed with a higher profit tax rate indeed redistributes towards innovative firms and thereby relaxes on net their finance constraint, making them invest more, $\hat{I}_c > 0$.

Profits of innovative firms in (15) and the innovation threshold in (16) change by

$$d\pi_c = -\pi_c \cdot \hat{\tau} + \rho p I_c \cdot \hat{I}_c, \quad \hat{q} = -(1 - \epsilon_{\tau,\sigma}) \cdot \hat{\sigma} - \frac{\rho p I_c}{\pi_c - \pi_u} \cdot \hat{I}_c. \tag{32}$$

The policy is much more favorable to innovative firms than an increase in the ACE tax since it boosts investment which yields an excess return to these firms. On net, the detrimental effect on profits is much reduced. For this reason, the innovation threshold strongly falls, not only because it directly benefits innovative firms ($\epsilon_{\tau,\sigma} < 1$). It also boosts investment which strengthens profits of innovative relative to standard firms and induces additional innovation. Average productivity θ_E rises on this account.

Since the tax reform is revenue neutral, $dT_E = 0$, welfare of entrepreneurs changes in line with net expected profit, $dv_E = d\pi_E$. Evaluating (18) results in

$$d\pi_E = [((1-\sigma) s_k k R - \bar{\pi}\epsilon_{\tau,\sigma}) + \rho p s_c I_c (\phi_\sigma - \phi_\tau \epsilon_{\tau,\sigma})] \cdot \hat{\sigma}. \tag{33}$$

Under the conditions mentioned above, the policy stimulates investment of constrained firms, $\hat{I}_c = (\phi_\sigma - \phi_\tau \epsilon_{\tau,\sigma}) \hat{\sigma} > 0$, which earns an excess profit and translates into higher expected profit π_E. When starting from an untaxed equilibrium, $\epsilon_{\tau,\sigma} = (1-\sigma) kRs_k/\bar{\pi}$ so that the first bracket is seen to be zero. A small self-financing R&D subsidy thus boosts expected profit and welfare by the second term. With a positive tax rate, substitute $\epsilon_{\tau,\sigma}$ and use the ϕ-coefficients in the numerator to get

$$(1-\sigma) s_k k R - \bar{\pi}\epsilon_{\tau,\sigma} = (\bar{\pi} - \pi_c s_k) \cdot \frac{\tau (x_c' - i) p s_c (1-\sigma) kR/m}{\bar{\pi} - \tau (x_c' - i) p s_c I_c \phi_\tau},$$

which is positive by (31). Hence, with few innovative and many standard firms, the condition on $\chi(q)$ is satisfied so that a self-financed R&D subsidy is welfare improving.

If all firms were unconstrained, all coefficients in (33) would be zero. In the absence of financial frictions, the ACE system would support a Pareto-optimal allocation so that a marginal, self-financed increase in the R&D subsidy would have a zero welfare effect!

Proposition 4 ***(R&D Tax Credit)*** *A revenue neutral increase in the R&D tax credit, leading to a subsidy larger than the tax rate, (i) redistributes towards innovative and constrained firms and boosts innovation. (ii) If there are relatively few innovative firms, the tax credit also stimulates investment of constrained firms and, (iii) yields first order welfare gains relative to non-discriminatory taxation.*

4.3.2 Tax Cut Cum Base Broadening

Tax cut cum base broadening restricts interest deductions (lower λ) to broaden the tax base and uses the extra revenue to cut the tax rate. While restricting interest deductions hurts all firms, the tax cut favors innovative firms. The tax cut boosts profits but not investment of standard firms since investment of these firms exclusively depends on user costs which do not change when an ACE system is in place. In contrast, the tax cut stimulates investment when it is sensitive to cash-flow, and therefore disproportionately boosts profits of innovating firms. Considering both measures together, the policy clearly retards investment of standard firms but holds a priori ambiguous incentives for innovating firms. We now show that the net investment response of constrained firms is positive.

Limiting interest deductions $\hat{\lambda} < 0$ broadens the tax base and allows for a lower tax rate such that fiscal revenue stays constant, $dT_E = 0$. When an ACE system is in place ($\sigma = \tau$ and $\lambda = 1$), the initial equilibrium implies $\rho = (1 - \tau)(x_c' - i)$ and $\pi_j = (1 - \tau)\pi_j^*$, where $\pi_j^* = p(x_j - iI_j)$, which leads to $\bar{\pi} = (1 - \tau)\bar{\pi}^*$ and $T_E = \tau(\bar{\pi}^* - s_k kR)$. Evaluating (20), noting (14), and using $\nabla_T = 0$ as shown in (21) yields

$$\hat{\tau} = \epsilon_{\tau,\lambda} \cdot \hat{\lambda}, \quad \epsilon_{\tau,\lambda} \equiv \tau \cdot \frac{pi\bar{I} - (x_c' - i)\, ps_c I_c \cdot (u_\lambda + \phi_\lambda)}{\bar{\pi} - \tau(x_c' - i)\, ps_c I_c \cdot \phi_\tau}. \tag{34}$$

Since $u_\lambda + \phi_\lambda = \tau ip/m$, the elasticity $\epsilon_{\tau,\lambda}$ is clearly positive as long as the excess return and the tax rate are not too large.

A lower deduction ($\hat{\lambda} < 0$) raises the user cost of capital, thereby harming standard investment. Innovative firms must also cut investment, as the inflated tax bill squeezes pledgeable income and thereby limits external funding. The marginal investment reduction has no effect on profits of standard firms but strictly reduces profits of constrained firms and thus the tax base. For this reason, the budget neutral cut in the tax rate is smaller than the pure mechanical effect would suggest. On the other hand, the lower tax rate has just the opposite effect. It boosts investment and profits of constrained firms and thereby augments the tax base so that the reduction in the tax rate can be even larger. The total impact is a magnification of the direct effect without tax base adjustments if $\epsilon_{\tau,\lambda} > \tau pi\bar{I}/\bar{\pi}$ which holds if $(x_c' - i)\, ps_c I_c \tau \left[\tau pi\bar{I}\phi_\tau - \bar{\pi}\,(u_\lambda + \phi_\lambda)\right] > 0$. After substituting the ϕ-coefficients, this is equivalent to

$$\epsilon_{\tau,\lambda} > \frac{\tau pi\bar{I}}{\bar{\pi}} \quad \Leftrightarrow \quad (x_c' - i)\, ps_c I_c \tau \cdot \frac{\tau ip\bar{I}}{m}\left[\frac{\pi_c}{I_c} - \frac{\bar{\pi}}{\bar{I}}\right] > 0. \tag{35}$$

The last paragraph of Appendix A shows that the average rent per unit of capital is larger for constrained firms. Hence, with an ACE system in place, the square bracket is positive. The inequalities $\pi_c/I_c > \bar{\pi}/\bar{I} > \pi_u/I_u$ hold since $\bar{\pi}/\bar{I}$ is an average.[10] This proves the magnification effect. If investment were unconstrained, $x_c' = i$ and $\pi_j/I_j = \bar{\pi}/\bar{I}$, there would be no magnification effect, leaving $\epsilon_{\tau,\lambda} = \tau pi\bar{I}/\bar{\pi} > 0$ only.

Investment of standard firms does not depend on the tax rate since the tax is neutral at the outset. On the other hand, base broadening by restricting interest deductions harms investment by $\hat{I}_u = u_\lambda \hat{\lambda} < 0$ as in (11). However, this marginal reduction of standard investment reduces neither profits nor welfare. When innovative firms are finance constrained, the tax cut cum base broadening policy boosts investment of these firms (evaluate 14 and use the ϕ-coefficients) if

$$\hat{I}_c = [u_\lambda + \phi_\lambda - \phi_\tau \epsilon_{\tau,\lambda}] \cdot \hat{\lambda} = -\frac{\pi_c \epsilon_{\tau,\lambda} - \tau ipI_c}{mI_c} \cdot \hat{\lambda} > 0 \quad \Leftrightarrow \quad \frac{\pi_c}{I_c} > \frac{\bar{\pi}}{\bar{I}}. \tag{36}$$

To see the sign restriction, note the magnification effect $\epsilon_{\tau,\lambda} > \tau pi\bar{I}/\bar{\pi}$. The numerator thus yields $\pi_c \epsilon_{\tau,\lambda} - \tau ipI_c > \pi_c \frac{\tau pi\bar{I}}{\bar{\pi}} - \tau ipI_c = \tau ipI_c \frac{\bar{I}}{\bar{\pi}}\left[\frac{\pi_c}{I_c} - \frac{\bar{\pi}}{\bar{I}}\right] > 0$. Since (35) must hold,

[10] Write $\bar{\pi}/\bar{I} = \left(s_c I_c / \sum_j s_j I_j\right) \cdot \pi_c/I_c + \left(s_u I_u / \sum_j s_j I_j\right) \cdot \pi_u/I_u$.

the revenue neutral tax cut cum base broadening policy boosts investment of innovative firms if they are finance constrained. In the unconstrained case with ϕ-coefficients being zero, investment would decline by $\hat{I}_c = u_\lambda \hat{\lambda} < 0$. The tax cut cum base broadening policy would impair investment of both innovative and standard firms.

In stimulating constrained investment which earns an excess return, the policy also favors profits of innovative relative to standard firms and, thereby, makes R&D spending more attractive. The innovation threshold falls by

$$\hat{q} = (\zeta_\tau \epsilon_{\tau,\lambda} - \zeta_\lambda) \cdot \hat{\lambda} < 0 \quad \Leftrightarrow \quad \pi_c/I_c > \bar{\pi}/\bar{I} > \pi_u/I_u. \tag{37}$$

To prove this, use $\epsilon_{\tau,\lambda} > \tau pi\bar{I}/\bar{\pi}$, substitute the ζ- and ϕ-coefficients and get

$$\zeta_\tau \epsilon_{\tau,\lambda} - \zeta_\lambda > \tau pi \left[\frac{\bar{I}}{\bar{\pi}} - \frac{I_c - I_u}{\pi_c - \pi_u}\right] + \frac{\rho p I_c}{\pi_c - \pi_u} \frac{\tau pi}{m} \frac{\bar{I}}{\bar{\pi}} \left[\frac{\pi_c}{I_c} - \frac{\bar{\pi}}{\bar{I}}\right] > 0,$$

where $\bar{I}/\bar{\pi} - (I_c - I_u)/(\pi_c - \pi_u) = \left[\left(\pi_c/I_c - \bar{\pi}/\bar{I}\right) I_c \bar{I} + \left(\bar{\pi}/\bar{I} - \pi_u/I_u\right) I_u \bar{I}\right] / \left[(\pi_c - \pi_u)\,\bar{\pi}\right]$ is positive in the constrained equilibrium. In the unconstrained case, $\epsilon_{\tau,\lambda} = \tau pi\bar{I}/\bar{\pi}$ and $\rho = 0$ so that the above equation would become $\zeta_\tau \epsilon_{\tau,\lambda} - \zeta_\lambda = \tau pi \left[\frac{\bar{I}}{\bar{\pi}} - \frac{I_c - I_u}{\pi_c - \pi_u}\right] = 0$ since average rents π_j/I_j would be identical across firm types. Again, the same policy would have no impact on innovation in the absence of finance constraints.

Finally, given revenue neutrality, welfare changes in proportion to net expected profit. Evaluating (18) and using $\hat{\tau} = \epsilon_{\tau,\lambda}\hat{\lambda}$ yields

$$d\pi_E = -\left[\left(\epsilon_{\tau,\lambda} - \tau pi\bar{I}/\bar{\pi}\right)\bar{\pi} + \rho p s_c I_c \cdot (\phi_\tau \epsilon_{\tau,\lambda} - u_\lambda - \phi_\lambda)\right] \cdot \hat{\lambda} > 0, \tag{38}$$

where $\phi_\tau \epsilon_{\tau,\lambda} - u_\lambda - \phi_\lambda > 0$ was already shown in (36) while the magnification effect $\epsilon_{\tau,\lambda} > \tau pi\bar{I}/\bar{\pi}$ holds by (35). Hence, all terms in the square bracket are positive in the constrained equilibrium. The tax cut cum base broadening policy thus boosts welfare. The unconstrained equilibrium, in contrast, is characterized by $\epsilon_{\tau,\lambda} = \tau pi\bar{I}/\bar{\pi}$ and $\rho = 0$, implying a zero welfare effect to the first order. The welfare result is intuitively clear when recognizing that the only distortion in the present model is the finance constraint on expansion investment of innovative firms. Since the policy relaxes this constraint, it allows for more investment of innovative firms and, thereby, creates net income gains in proportion to the excess return of these companies.[11]

Proposition 5 ***(Tax Cut Cum Base Broadening)*** *Starting with undistorted user costs of capital, a smaller deduction of financing costs and a revenue neutral cut in the tax rate redistributes towards innovative firms and (i) boosts innovation; (ii) raises (reduces) investment of constrained (unconstrained) firms; and (iii) raises welfare.*

5 Conclusions

Even in advanced economies with a well developed financial sector, many firms – and typically the most innovative ones – tend to be financially constrained for several reasons. First, they often spend considerable resources on R&D which drains own funds available for self-financing of equipment investment and restricts external leverage. Secondly, because they are more innovative, they have more profitable investment opportunities and need large external funds to grow. Finally, these firms are often closely held companies driven by entrepreneurs who possess key technological know-how and inalienable human capital. Since their input is essential for the development of the company, they must keep a large enough stake to assure full effort and commitment to the firm. However, the entrepreneur's stake subtracts from pledgeable income that can be promised to external investors as a credible repayment and thereby limits the firm's financing capacity. In contrast to standard firms, constrained innovative firms earn a return in excess of the user cost of capital because the limited capacity for external financing prevents them to fully exploit the opportunities to invest. Stimulating investment of constrained firms thus boosts income and welfare in the economy.

[11] Substituting coefficients, we can show the first term in (38) to be proportional to the excess return,

$$\epsilon_{\tau,\lambda} - \tau pi\bar{I}/\bar{\pi} = (x_c' - i)\,\tau \frac{ps_c I_c \left(\pi_c/I_c - \bar{\pi}/\bar{I}\right) \tau pi\bar{I}/m}{\left[\bar{\pi} - (x_c' - i)\, ps_c I_c \cdot \tau\phi_\tau\right] \bar{\pi}}.$$

The presence of constrained firms has important implications for tax policy. While taxes affect investment of standard firms via the traditional user cost channel, user costs and effective marginal tax rates are not relevant for constrained firms. Instead, investment becomes sensitive to future cash-flow and own internal resources which determine possible external funding. In this paper, we have proposed a framework of heterogeneous firms where an early stage R&D decision endogenously divides the business sector into constrained and unconstrained firms. We have found, among others, the following novel results on the effects of business taxation: First, R&D subsidies not only encourage innovation but also relax finance constraints and help innovative firms to exploit investment opportunities to a larger extent. Second, introducing a profit tax which would be neutral in the neoclassical world, restricts expansion investment of constrained firms by reducing free cash-flow and thereby discourages innovation. Even a small tax reduces welfare to the first order. Third, a revenue neutral increase in profit taxes to finance larger R&D subsidies redistributes towards innovative firms and may boost aggregate productivity and welfare. Finally, a revenue neutral tax cut cum base broadening policy similarly favors constrained firms and boosts innovation and welfare.

Appendix

A Interior Solution: An interior solution as illustrated in Figures 1 and 2 is guaranteed by suitable parameter restrictions. We restrict k, A, θ, and β such that four conditions are fulfilled: (i) standard firms are not constrained; (ii) innovative firms are credit constrained; (iii) innovative firms invest more than standard firms, $I_c > I_u$; and (iv) only a share of firms chooses R&D, $0 < q < 1$. The difference $AR - A_cR$ on the vertical axis of Figure 1 corresponds to the fixed R&D cost $(1-\sigma)\,kR$. For any given θ, one can set $A(\theta)$, $k(\theta)$ and $\beta(\theta)$ to satisfy the first three restrictions. Figure 1 illustrates a representative case where necessarily $\pi_c > \pi_u$ on account of $\theta > 1$. As a last step, we vary θ to obtain a profit differential $\pi_c - \pi_u$ such that $q < 1$ in (7). In subsequent analysis, we also compare constrained allocations $I_c < I_c^*$ with unconstrained ones, $I_c = I_c^*$. If not constrained, innovative firms choose I_c^* instead of I_c as given by (6). Holding all other parameters constant, this case can always be created by reducing β which reflects the benefits of shirking. The upward sloping broken lines in Figure 1 would become flatter.

We also show for subsequent analysis that, for the case of an isoelastic technology $x = \theta f(I)$ with $f(I) = I^\alpha$ and $0 < \alpha < 1$, the average rent $\tilde{\pi}_j \equiv (1-\tau)\left[\theta_j f(I_j) - uI_j\right]/I_j$ per unit of capital is larger for innovative and financially constrained firms, $\tilde{\pi}_c > \tilde{\pi}_u$. Note first that higher productivity induces larger investments if all firms were unconstrained, i.e. $\theta_j f'\left(I_j^*\right) = u$ implies $I_c^* > I_u^*$. Obviously, investment rises with productivity, $dI_c^*/d\theta = -f'/\left(\theta f''\right) > 0$. The functional form yields the solution $I_c^* = (\theta\alpha/u)^{1/(1-\alpha)}$. *Average rent* $\tilde{\pi}\left(I_j^*\right) = (1-\tau)\left[\theta f\left(I_j^*\right)/I_j^* - u\right] = (1-\tau)\, u\,(1-\alpha)/\alpha$ is independent of θ. If all firms were unconstrained, the productive ones would invest more but have the same rent $\tilde{\pi}$ per unit of capital. However, when investment of innovative firms with given productivity θ is constrained below the optimal level, average rent of these firms becomes higher since $\tilde{\pi}'(I) = -(1-\tau)\,\theta\left[f(I) - If'(I)\right]/I^2 < 0$ by concavity. The envelope theorem does not hold since the marginal return is not equal to the user cost. Hence, restraining investment boosts average rent, $\tilde{\pi}_c > \tilde{\pi}_u$.

B Capital and Output Market Equilibrium: Deposit market equilibrium requires $A(1-E) + A_c(s_k - s_c)E + A(1 - s_k - s_u)E = \sum_j (I_j - A_j)\, s_j E + \sigma k s_k E + Z$. The left hand side states supply of loanable funds consisting of (i) savings of $1-E$ investors; (ii) residual savings $A_c = A - (1-\sigma)k$ of failed innovators; and (iii) savings A of failed standard firms. Demand on the right hand side consists of (i) credits for expansion investment of both types of firms; (ii) public debt to pay R&D subsidies at the beginning of period; and (iii) investments in international bonds or in a safe Z-technology, see the first paragraph of Section 2.1. Rearranging yields

$$A - K \cdot E = Z, \quad K \equiv s_k k + \textstyle\sum_j s_j I_j, \tag{A.1}$$

where K denotes total investment per firm. If r is the fixed productivity of a safe Ricardian technology, then Z is residual savings invested in the Ricardian sector. If r is an internationally fixed deposit rate, Z denotes capital exports or imports, depending on whether national savings A exceed or fall short of national investment KE.

Private consumption is equal to end of period wealth $Y = (AR + \pi_E + T_E)\, E + AR\,(1 - E)$ of investors and entrepreneurs. Substituting π_E and T_E and other definitions such as $\pi_j + pT_j = p\,(I_j + x_j) - I_j R$ and K, defining aggregate output of the entrepreneurial sector $X \equiv \sum_j p\,(I_j + x_j)\, s_j E$, and using (A.1) yields the output market condition $Y = ZR + X$. If ZR is end of period output from investments in the Ricardian technology, then consumption Y is equal to aggregate sectoral output. Alternatively, the output market condition can be stated as $Y - X = ZR$ where imports $Y - X$ is paid by foreign source earnings on capital exports Z.

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